1 405 487

PATENT SPECIFICATION (11) 1 405 487

(21) Application No. 44494/72 (22) Filed 26 September 1972
(23) Complete Specification filed 12 September 1973
(44) Complete Specification published 10 September 1975
(51) INT CL² B23K 26/00 B28D 1/14 1/22
(52) Index at acceptance
B3V 4A2C
B3R 31 37A3
B5E X8
G2J 32

(72) Inventor MAURICE GEORGE CLARKE

(54) IMPROVEMENTS IN OR RELATING TO APPARATUS FOR TREATING WORKPIECES WITH LASER RADIATION.

(71) We, THORN ELECTRICAL INDUSTRIES LIMITED, a British company, of Thorn House, Upper Saint Martin's Lane, London WC2H 9ED, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to apparatus for treating workpieces with laser radiation.

Laser radiation has been found to be useful for boring, cutting, and welding small workpieces.

If a small workpiece is subjected to several pulses of laser radiation directed one after the other to different points on the workpiece, the workpiece may be distorted. Furthermore, special arrangements are necessary to enable the source of the pulses to be moved to direct the pulses to the different points on the workpiece.

The principal object of the present invention is to provide apparatus by means of which a workpiece can be treated with laser radiation at a plurality of different points simultaneously.

According to the present invention there is provided apparatus for treating workpieces with laser radiation, the apparatus including a laser arranged to direct a beam of laser radiation, when generated thereby in operation, into means for focussing the radiation simultaneously at a plurality of spaced focal points, the said means comprising an optical system which when transmitting the generated radiation focusses the radiation passing through each one of at least two mutually exclusive areas of the cross-section of the beam at a respective point, the points being spaced from each other, wherein the optical system includes a plurality of refracting members one or more of which intercepts the whole beam and renders the beam convergent, and another one or more of which is a prism having a pair of plane faces, through which part of the convergent beam passes in succession so that the prism deviates the radiation in at least one of the said mutually exclusive areas by a predetermined angle from its path before its entry into the respective prism.

In a preferred embodiment the focussing means may include a plurality of prisms of which has a pair of plane faces through which radiation in a plurality of the said mutually exclusive areas passes in succession.

Preferably, means are provided for varying the relative positions of the prisms.

Examples of embodiments of the present invention will now be described with reference to the drawings filed with the Provisional Specification in which:

Figures 1, 2, 3 and 4 are diagrammatic side views of different optical systems in different embodiments of the invention, and

Figures 1*a*, 2*a*, 3*a* and 4*a* are plan views of parts of the optical systems of Figures 1 to 4 respectively.

The term "optical system" is used herein to refer to any system which acts upon a beam of laser radiation in a manner which can be described by treating the laser radiation as light.

In Figure 1 of the drawings there is shown an optical system 10 of an apparatus embodying the present invention. The optical system 10 is arranged to receive, in operation, a substantially parallel beam of laser radiation travelling parallel to the axis of a compound converging lens 11 constituting one refracting member of the system 10. The lens 11 intercepts the whole beam of laser radiation.

Adjacent the side of the lens 11 from which the beam of laser radiation, emitted by a source not shown, emerges is a plane faced Fresnel biprism 12 arranged with its apex

edge 13 perpendicularly bisected by the axis of the compound lens 11, this axis lying in the plane which bisects the angle between the two faces of the prism 12 which meet at the apex edge 13.

Those skilled in the art will realise that the system 10 produces two focal points 14 and 15 at which laser radiation is concentrated in a focal plane 16 of the system. The points 14 and 15 are indicated by the termini of two rays 17 and 18 shown in Figure 1.

In operation the lens 11 renders the beam convergent, one half of the biprism 12 selects the radiation passing through one area of the cross-section of the beam and deviates the selected radiation to one of the points 14 and 15, and the other half of the biprism 12 selects the radiation passing through another area of the cross-section of the beam and deviates the selected radiation to the other of the points 14 and 15. The said areas do not overlap and therefore are mutually exclusive.

Figure 1*a* shows the biprism 12 viewed from the adjacent face of the lens 11.

The distance apart of the points 14 and 15 can be adjusted finely by varying the axial distance of the biprism 12 from the lens 11.

If desired, the positions of the lens 11 and the biprism 12 may be interchanged.

Movement of the biprism 12 perpendicular to its apex edge 13 in a plane to which the axis of the lens 11 is perpendicular changes the respective proportions of the beam directed to the points 14 and 15 without altering their positions. Hence such movement of the biprism can be used to control the amount of laser radiation received at each point 14 and 15, and will hereinafter be termed, for convenience, lateral movement of the biprism, or prism as the case may be. If two separate prisms, each corresponding to one half of the biprism 12, are used instead of the biprism 12, the amounts of laser radiation at the points 14 and 15 can be varied independently by independent lateral movement of the two prisms.

Figure 2 shows an optical system 20 of a second embodiment of the invention for focussing a beam of laser radiation at three points 24, 25 and 27 in a focal plane 26.

The system 20 has a compound convergent lens 21 and two plane faced prisms 22 and 23.

The lens 21 is arranged to intercept the whole beam of laser radiation, whereas each of the prisms 22 and 23 intercepts a respective part only of the beam. The prisms 22 and 23 are spaced apart so that radiation which passes between the prisms 22 and 23 is undeviated after emerging from the lens 21 and converges to one of the three focal points, 27, which lies on the axis of the lens 21 at the plane 26. Radiation which passes through the lens 21 and the prism 22 is focussed at a second one of the three points, 24, and radiation which passes through the lens 21 and the prism 23 is focussed at a third one of the three points, 25.

Figure 2*a* is a view similar to that of Figure 1*a* but of the prisms 22 and 23 of Figure 2.

Figures 3 and 3*a* show in like manner to Figures 2 and 2*a* an optical system 30 of a third embodiment of the invention for focussing a beam of laser radiation at five points in a focal plane 36. The system 30 differs from the system 20 in having, in addition to a lens 31 and two prisms 32 and 33, a further pair of prisms 34 and 35. The prisms 34 and 35 are smaller than the prisms 32 and 33 as shown in Figures 3 and 3*a* and are arranged to intercept respective parts only of the respective portions of the beam which are intercepted by the prisms 32 and 33. Thus in addition to the three focal points given by the system 20 of Figures 2 and 2*a*, the system 30 by further deviating two portions of the beam by means of the prisms 34 and 35 provides two more focal points.

In the embodiments so far described, the two or more focal points are distributed along a line through which the axis of the lens 11, 21 or 31 passes. This is due to the fact that the differences in path length introduced by the prisms vary across planes parallel to only one plane containing the axis of the lens 11, 21 or 31. The line of intersection of this plane with the focal plane 16, 26 or 36 is the line along which the focal points are distributed.

Figures 4 and 4*a* show an optical system 40 of a fourth embodiment of the invention. The optical system 40 differs from the systems 10, 20 and 30 in having two planes in which the axis of a lens 41 is contained and differences in path length varying transversely of the axis of the lens 41 are introduced by four prisms 42, 43, 44 and 45, each of which is similar to the prism 22 or 23 of Figure 2. The four prisms 42 to 45 are arranged in two pairs. The first pair, 42 and 43, are arranged relative to the lens 41 in the same way as the prisms 22 and 23 are arranged relative to the lens 21. The second pair, 44 and 45, are arranged to lie with their lengths perpendicular to the direction of the lengths of the first pair and adjacent the faces of the prisms 42 and 43 remote from the lens 41. The prisms of each pair are spaced from one another so that a central square area of the cross-section of a beam of laser radiation can, after emerging from the lens 41, pass without deviation to the principal focal point 47 of the lens 41 in a focal plane 46.

The arrangement of the four prisms 42 to 45 provides eight different groups of paths for different portions of the beam, the group of paths differing in location transversely of the axis of the lens 41, and circumferentially alternating in the number of prisms traversed, there being four groups, each cor-

responding to the central portion of a respective one of the prisms, in which only the respective one prism is traversed, and four groups, each corresponding to two overlapping end portions of a pair of adjacent prisms, e.g. 42 and 45, in which the two overlapping prisms are traversed.

Thus eight more focal points, 48 to 55, are provided.

In all the optical systems shown in the accompanying drawings, the means for producing a convergent beam, the lens 11, 21, 31 or 41, is a separate member, the convergence of the beam being unaffected by the prisms of the system. Other embodiments can be constructed in which one or more refracting members of the system not only render the radiation incident thereon convergent, but also deviate that radiation as a whole away from the direction of travel of the incident beam. Furthermore, such members may confer different degrees of convergence so that the resultant focal points do not all lie in the same plane. Alternatively, embodiments can be constructed, where no relative adjustment of the focal points is required, by forming systems such as those of the drawings as a single integral refracting member.

Where an embodiment of the invention is to be used for welding, boring or cutting metals a laser producing radiation in either the visible or near infra-red bands of the electromagnetic spectrum may be utilised, and the lenses and prisms may be made from a glass or quartz. However if certain non-metallic materials such as Silica are to be machined, it may be preferable to use a longer wavelength infra-red radiation such as 10.6 microns which is emitted from a carbon dioxide laser. This may necessitate using refractive elements manufactured from a synthetic salt crystal or germanium.

Anti-reflection "blooming" coatings suitable for the particular wavelength of laser radiation employed may be applied to the surfaces of prisms and/or other refracting members through which the radiation is to pass to minimise losses.

WHAT WE CLAIM IS:—

1. Apparatus for treating workpieces with laser radiation, the apparatus including a laser arranged to direct a beam of laser radiation, when generated thereby in operation, into means for focussing the radiation simultaneously at a plurality of spaced focal points, the said means comprising an optical system which when transmitting the generated radiation focusses the radiation passing through each one of at least two mutually exclusive areas of the cross-section of the beam at a respective point, the points being spaced from each other, wherein the optical system includes a plurality of refracting members one or more of which intercepts the whole beam and renders the beam convergent, and another one or more of which is a prism having a pair of plane faces through which part of the convergent beam passes in succession so that the prism deviates the radiation in at least one of the said mutually exclusive areas by a predetermined angle from its path before its entry into the respective prism.

2. Apparatus according to claim 1, wherein there is a plurality of prisms each of which has a pair of plane faces through which radiation in a plurality of the said mutually exclusive areas passes in succession.

3. Apparatus according to claim 1 or 2, wherein there is a plurality of prisms and means are provided for varying their relative positions.

4. Apparatus for treating workpieces with laser radiation substantially as hereinbefore described with reference to Figure 1 and 1*a*, or 2 and 2*a*, or 3 and 3*a*, or 4 and 4*a* of the drawings accompanying the Provisional Specification.

REDDIE & GROSE
Agents for the Applicants,
6 Bream's Buildings,
London EC4A 1HN.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1975.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1405487 PROVISIONAL SPECIFICATION
1 SHEET
This drawing is a reproduction of the Original on a reduced scale

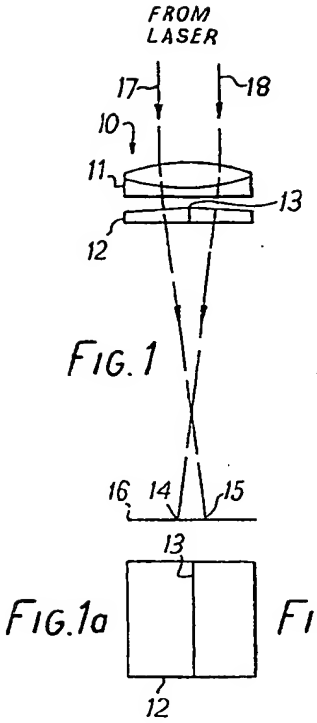

FIG. 1

FIG. 1a

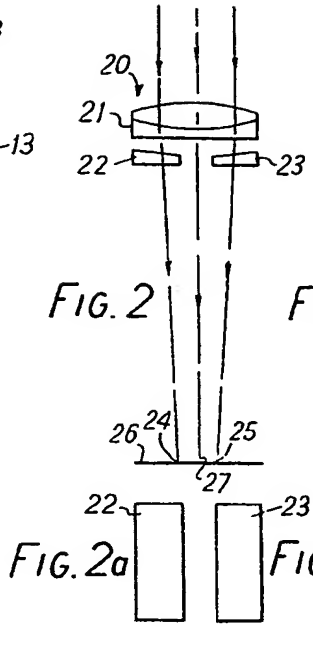

FIG. 2

FIG. 2a

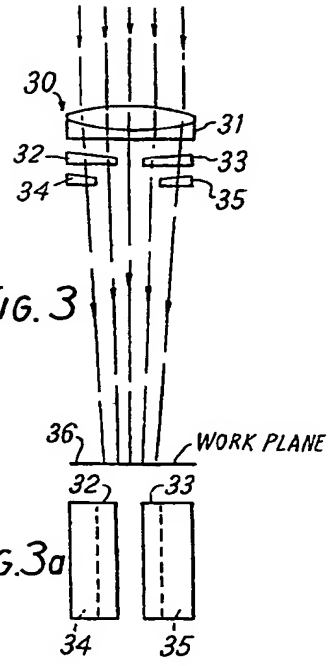

FIG. 3

FIG. 3a

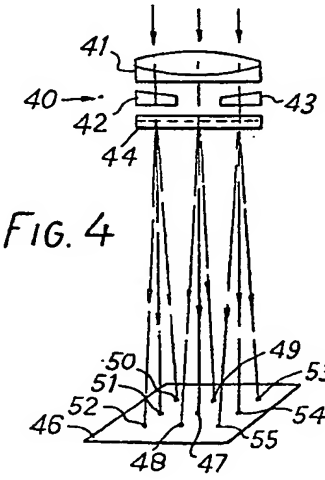

FIG. 4

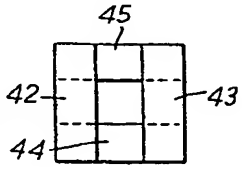

FIG. 4a